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DEVELOPMENT OF A LIGHTWEIGHT AMMUNITION CONCEPT USING AN ALTERNATIVE CASE MATERIAL AND ENHANCED PROPELLANT

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Soldiers are carrying additional high technology equipment to increase effectiveness at additional weight. To achieve a significant weight reduction and to enhance soldier's effectiveness, the Joint Service Small Arms Program Office is developing a Lightweight Family of Weapons and Ammunition. The ammunition concept developed during this contract combines a lightweight cartridge case and a high-density consolidated propellant charge that substantially reduces the cartridge volume. This report describes the lightweight cartridge case development from conception , thermally consolidated propellant fabrication and testing.

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INTRODUCTION

Overview

The Army's proposed concept for the Objective Force Warrior (OFW) will enhance warfighter lethality and survivability. The OFW will have "full spectrum capabilities", meaning that troops can use it for any mission from peacekeeping to high-intensity conflicts. Plans include the addition of many new capabilities to provide that level of flexibility. These new advances in weapon systems result in soldiers carrying additional high tech equipment to enhance effectiveness, but at the cost of increased weight. It is important that the warfighter become more effective and make use of the added capability provided by the OFW initiative, and not merely discard these tools when the fighting becomes more intense or mobile. Consequently, it is desirable for the OFW system to be implemented with an actual reduction in weight. This requires a significant weight reduction for weapons and ammunition without sacrificing warfighter effectiveness or safety.

To achieve a significant weight reduction and enhance soldier effectiveness, the Joint Service Small Arms Program Office (JSSAP), Armament Research, Development and Engineering Center (ARDEC), Picatinny, New Jersey is developing a Lightweight Family of Weapons and Ammunition (LFWA). As part of this initiative, advanced gun and ammunition system design technologies are being investigated to develop smaller and lighter components and end items without sacrificing performance and safety. The objective of the subject contract is to develop lightweight small caliber ammunition with concomitant weight and volume benefits for the entire weapon system.

The ammunition concept developed during this project combines a lightweight cartridge case and a high-density consolidated propellant charge that substantially reduces the cartridge weight and volume. Reducing the size and weight of the ammunition cartridge creates opportunities for synergistic weight reduction in weapon design and in ammunition packaging materials. Furthermore, reducing the volume and weight of the ammunition reduces the burden on the logistics train and enables the warfighter to carry additional rounds of ammunition or other equipment that will enhance combat effectiveness.

Replacement of heavy ammunition cartridge cases made of brass or steel with cases made of advanced lightweight materials will considerably reduce the weight burden associated with the ammunition. By incorporating other advanced ammunition design elements, ammunition weight can be further reduced.

Objective

The objective of this program was to develop and demonstrate a lightweight ammunition concept, in 7.62-mm caliber, which maximizes potential weight savings without compromising functionality of the ammunition. Previous lightweight ammunition development programs have investigated aluminum or polymer cartridge case replace-ments, or elimination of the cartridge case altogether, with varying degrees of success.

Since the intent of this BAA was to take a clean sheet approach to lightweight ammunition and weapon design, an ammunition concept was developed that provides most of the weight reduction benefits of caseless ammunition, but at reduced risk. Three areas of

potential improvement over the existing conventionally cased ammunition (e.g., M80, M855) were identified: ammunition weight, ammunition size, and ballistic performance. Reduction of the ammunition weight was the primary goal, with a target of at least 30%, which was accomplished mainly through use of a lightweight cartridge case. Reducing the ammunition size or volume as much as deemed feasible was also an important design goal, which was accomplished using thermally consolidated propellant. While increased performance could also be achieved, there was no requirement for this. As a result, the program objective was to meet the performance and safety characteristics of current conventional ammunition, while achieving the weight reduction cited. These objectives allow the weight and volume reduction efforts of the subject program to be evaluated with respect to currently fielded conventional ammuni-tion with the same performance.

LIGHTWEIGHT AMMUNITION

Small caliber ammunition must perform dependably and consistently in a wide range of environmental conditions, survive handling during transport and loading, and maintain functionality over a 20-yr storage life. The lightweight ammunition concept developed during this project incorporates a thermally consolidated propellant that reduces the volume occupied by the propellant, and thus reduces the size of the ammunition, and a lightweight cartridge case that reduces the weight of the ammunition and provides protection from rough handling and the environment. The caliber selected for this development effort was 7.62 mm and the ballistic performance target was the M80 ball ammunition.

Thermally Consolidated Propellant

The normal loading density for a loose granular propellant charge is between 0.9 and 1.0 gm/cm^3. To increase the chemical propulsive energy using the available chamber volume and a given propellant formulation, the charge can be compressed or compacted to higher densities. Conversely, compaction can be used to decrease the volume occupied by the propellant, while maintaining the chemical propulsive energy. Simple compaction at room temperature can be used to achieve somewhat higher densities without propellant damage; however, as compaction density is further increased, the occurrence of propellant grain fracture becomes more likely, especially if the propellant has non-optimal mechanical properties.

Higher compaction densities and greater structural integrity can be obtained if the propellant is consolidated or bonded during the compaction process. The thermal coating material that produces bonding of the propellant grains also tends to lubricate the propellant, giving it increased mobility during the consolidation process. Veritay has successfully consolidated propellant charges for large caliber ammunition that include a 105-mm tank round, 155-mm howitzer charge increment, and a 120-mm tank round (TERM KE). There is also a large base of experience at Veritay for consolidation of small caliber (5.56-mm caseless round) propellant, which has been consolidated to densities greater than 1.5 gm/cm^3 and medium caliber (20 mm, 25 mm, and 30-mm cannon) propellants to densities greater than 1.4 gm/cm^3. With proper grain design and care during the consolidation process, charge densities up to 1.5 gm/cm^3 can be achieved with granular propellant for small caliber applications. Thus, consolidation is a method by which the propellant volume can be decreased approximately 30% for most propellant formulations, and in virtually any gun caliber.

A thermal consolidation process that was developed in France by SNPE (now EURENCO), licensed in the United States by Veritay Technology, Inc. and subsequently sublicensed to the U.S. Government, is mature in development and exhibits superior characteristics. The process involves coating propellants with an energetic thermoplastic material that softens when heated. The heated coating material tends to lubricate the propellant and mold during consolidation and forms a dimensionally stable, structurally strong bond when cooled. The bond strength is diminished by only 20% when the consolidated charge is re-heated to 70°C, the maximum required ammunition storage temperature. Veritay has successfully consolidated small caliber granular propellants using the SNPE process to a density of 1.5 gm/cm^3 and conducted firing tests with the resulting charges to demonstrate ballistic performance characteristics.

Alliant TechSystems/Radford AAP has developed an inert thermal coating for use in propellant consolidation. This process involves coating propellant with an inert material and subsequently performing the consolidation operation at elevated temperatures as with the SNPE process. The use of an inert coating material tends to deter or inhibit ignition, depending on the amount used to coat the grains. Veritay has developed processes to consolidate propellant charges using the Alliant coating for the TERM KE advanced 120-mm tank ammunition where this inhibition effect is desirable.

Because the propellant is hot during the thermal consolidation process, the grains are relatively soft and easily deformed, which helps to achieve high compaction densities while experiencing only minimal (if any) propellant grain fracture. During combustion, the consolidated propellant charges effectively deconsolidate into the granules from which they were formed, thereby maintaining essentially the same combustion form function as the loose propellant prior to consolidation. To date, the thermoplastic coating materials have been applied to a variety of propellant formulations that include single base, double base, triple base, and low vulnerability [high ignition temperature (HITP)] nitramine-based propellants. In principle, the coatings may be applied to almost any propellant formulation.

Three single-base propellants coated with the SNPE energetic thermoplastic binder were selected from Veritay's inventory for use in developing the lightweight ammunition. A fast burning propellant is necessary for small caliber applications where the projectile mass is low and the action time short. This is especially important because the consolidation process tends to depress the initial rate of the combustion gas generation due to reduction of the propellant surface area. Thus, consolidation produces a degree of combustion progressivity independent of the propellant granulation. This is advantageous for consolidated propellant applications because the initial free chamber volume is low compared to conventional ammunition.

An example of the consolidated propellant charge production mold is shown in figure 1. The example of a thermally consolidated propellant charge (fig. 2) illustrates how a granular propellant is compressed to a high density without significant grain deformation or fracture. The propellant used during this project was provided by Veritay at no cost to the government.

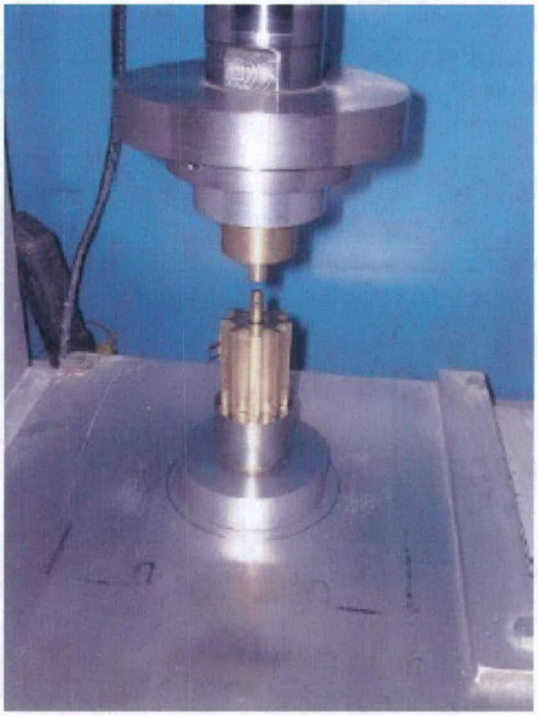

Figure 1
Propellant consolidation mold

Figure 2
Consolidated propellant charge

Lightweight Ammunition Ballistic Evaluation

Ballistic evaluation of the lightweight ammunition concept was performed using two single-shot ballistic test fixtures designed and fabricated at Veritay. Initial interior ballistic development was performed in a fixture designed to fire the candidate ammunition without a cartridge case, using a chamber that replicated the interior dimensions of the cartridge case.

Excluding the cartridge case from initial testing had two benefits: chamber pressure could be directly measured at several locations with piezoelectric pressure transducers, and the cost and time involved in making cartridge cases could be avoided during the initial development phase. Once the propelling charge was developed, subsequent evaluation of lightweight cartridge case designs was performed using a chamber designed for the cased ammunition. Both fixtures used a M240B machine gun barrel, provided by Veritay, which was modified to accept interchangeable chambers.

The single-shot ballistic test fixture for cased ammunition is shown in figure 3. Instrumentation included a PCB 117 piezoelectric pressure transducer for measuring the chamber pressure through the cartridge case wall, two PCB 119 pressure transducers at down-bore locations, and four Veritay Type-K in-wall thermocouples for measuring barrel heating. Additional instrumentation included optical velocity sensors for measuring muzzle velocity, high-speed photography (fig. 4), and witness cards for determining bullet flight attitude.

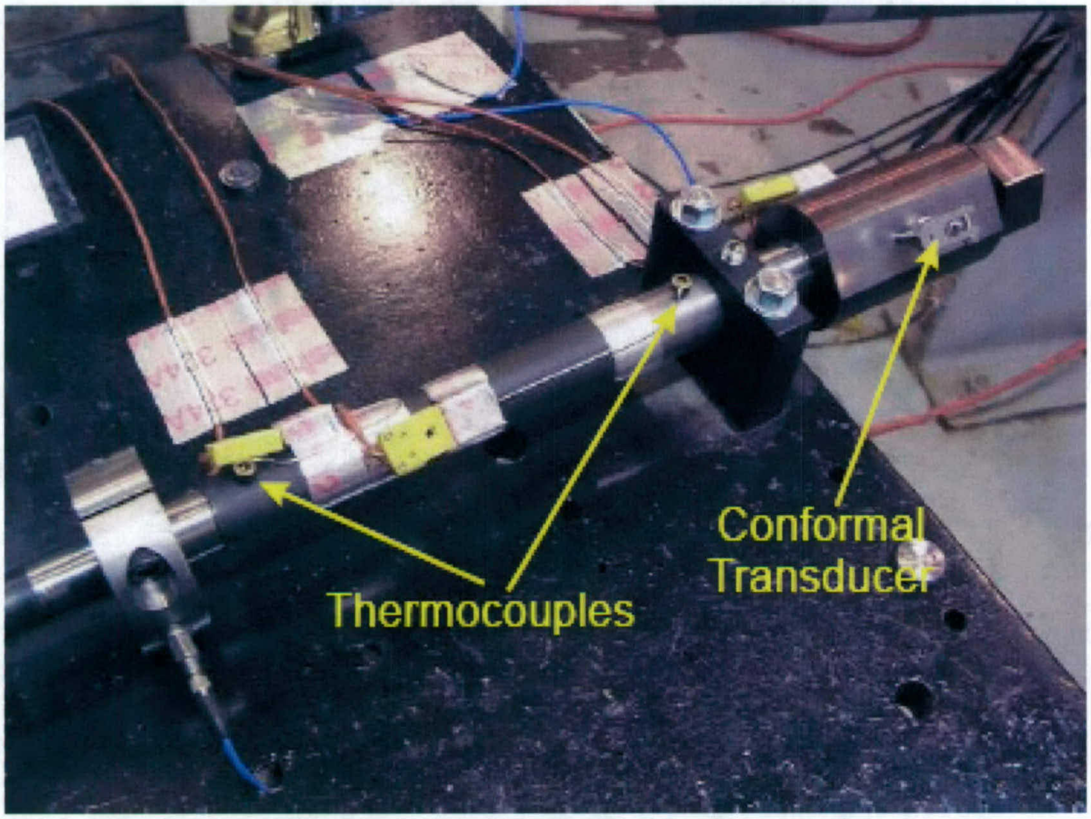

Figure 3
Single-shot ballistic test fixture

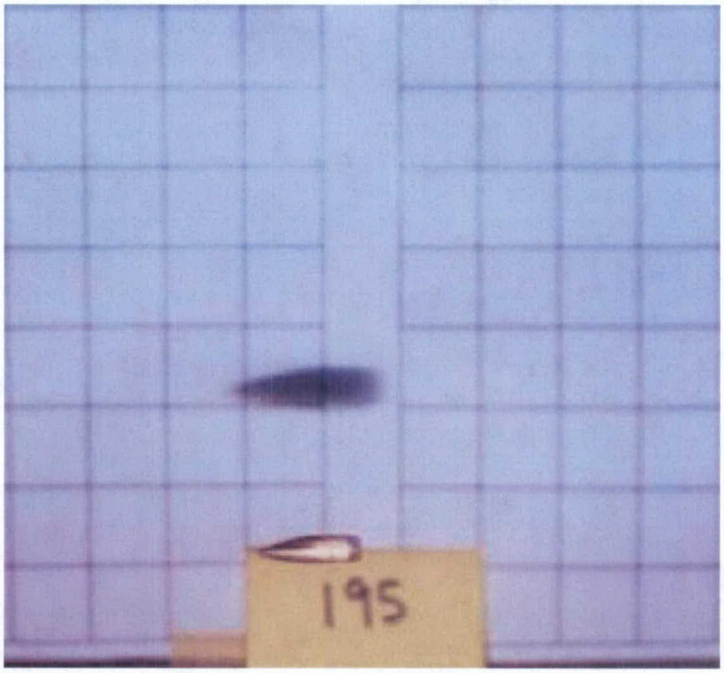

Figure 4
High-speed photograph of bullet in flight

An evolutionary approach was taken to the lightweight ammunition development process, with key design parameters defined and varied to gauge their effect on ammunition function and performance. The ammunition was developed through a process of experimental ballistic evaluation supported by computer simulation using the IBHVG2 (**I**nterior **B**allistics of **H**igh **V**elocity **G**uns version **2**) code. The propellant used for this project was produced for a different program and was not optimized for the current ammunition application. As a result, a propellant mass equivalent to the M80 (46 gr) could not be used without expelling unburned propellant from the gun. Therefore, a smaller charge mass than desired (38.8 gr, 15.6% less than the M80) was used during the current program, which resulted in lightweight ammunition performance that was slightly lower than for the M80. The final lightweight ammunition configuration yielded a muzzle velocity that was somewhat (9%) less than that of the M80.

Optimization of a propellant for this application (propellant geometry and formulation) would ensure that all of the propellant is consumed during the ballistic event, thereby increasing muzzle velocity to levels commensurate with the M80. Alternatively, advanced higher energy propellant formulations would enable the performance goals to be met with a reduced propellant mass, further reducing the weight of the ammunition. Ballistic repeatability measured by peak chamber pressure and muzzle velocity was very good, considering the developmental nature of the ammunition. A series of pressure time curves for repeat firings of the final ammunition configuration are shown in figure 5.

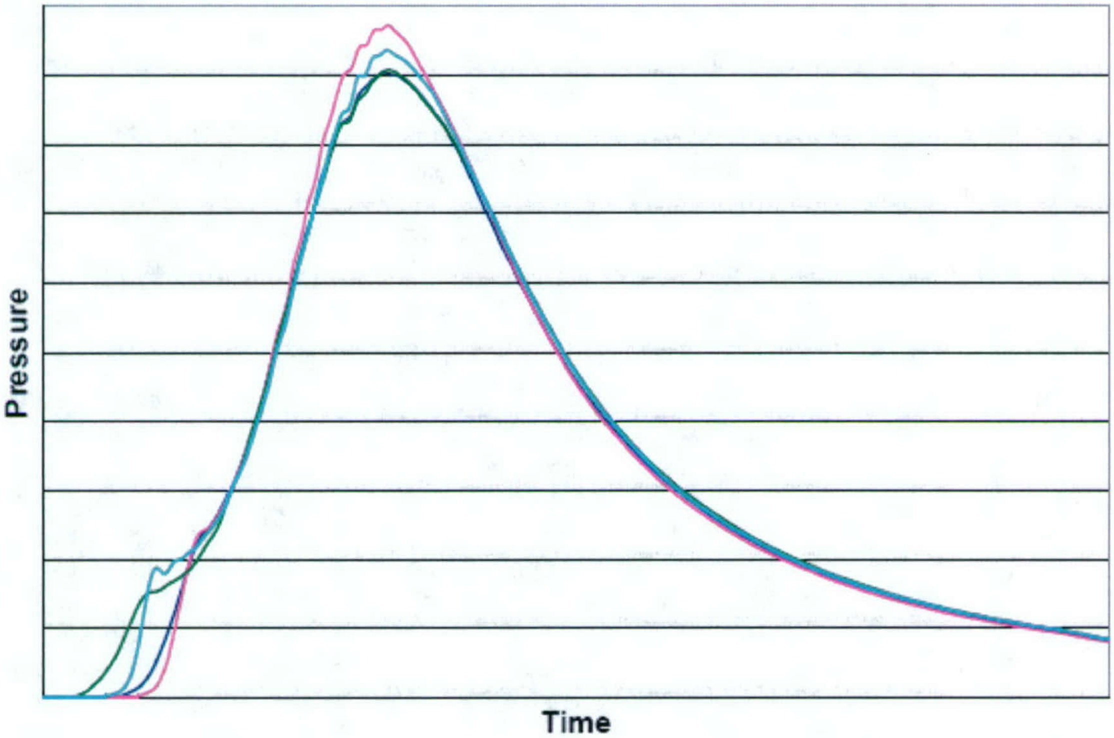

Figure 5
Chamber pressure-time curves for the lightweight ammunition

Lightweight Cartridge Case

Much of the weight reduction in the lightweight ammunition developed during this project was derived from the use of materials other than brass for the cartridge case. Elimination of the cartridge case altogether (i.e., caseless ammunition) is the ultimate goal; however, a cartridge case plays an important role in the reliability of the ammunition. Environmental protection is an important function of the cartridge case, particularly the exclusion of moisture. Mechanical protection is also an important function of the cartridge case during shipping, handling, and loading. Cased ammunition has a particular advantage over caseless ammunition when heat management is considered. Much of the heat generated by the burning propellant will be contained within the cartridge case when it is ejected from the weapon, which will reduce the heating rate of the chamber region. In caseless ammunition, the heat will be convected into the chamber, possibly requiring a means of cooling the chamber during sustained firing. Finally, the cartridge case performs the function of sealing the gun chamber and firing pin during a firing. In caseless ammunition, this function must be transferred to the weapon design, potentially complicating the design and increasing the weight of the weapon itself.

Research and development of lightweight cartridge case materials has been ongoing for many years and has included study of alternate materials such as aluminum and plastics. The ammunition developed during this project can make use of a variety of alternative cartridge case materials, including aluminum and polymers. Both aluminum and polymer cases have unique failure modes; however, the weapon design can mitigate many of the failure conditions. Regardless of the material type, metallic or plastic, the case material must meet several requirements. The case material needs to balance ductility, strength, and toughness to survive the ballistic event. The material must be able to withstand the thermal input from burning propellant, as well as from exposure to heated weapon components during burst fire. Chemical compatibility with the propellant is very important for the long-term storage of the ammunition.

Ammunition Weight Distribution

The combination of a thermally consolidated propellant and a lightweight cartridge case produce ammunition with significant weight reduction compared to conventional ammunition. The performance target of this project was to design a 7.62-mm cartridge that weighed at least 30% less than the existing M80 cartridge. Considering just the cartridge (i.e., no packaging or links), the 7.62-mm lightweight ammunition is 36.5% lighter than the M80 cartridge. If the lightweight ammunition is used in a linkless feed system, the weight benefit is even greater, yielding a 45.7% weight reduction compared to the M80 ammunition with M13 links.

Figure 6 shows the weight distribution for the lightweight ammunition developed during this project. The total combat load for 600 rounds of ammunition is 21.22 lbs, not including packaging materials. In comparison, the total combat load for 600 rounds of M80 ball ammunition is 33.43 lbs, not including packaging, and the weight distribution is shown in figure 7. Reducing the ammunition weight by over 12 lbs can significantly reduce the burden on the warfighter, or conversely, allow the individual to carry additional gear or ammunition. For an equivalent weight, an individual could carry 600 rounds of conventional M80 ammunition or 945 rounds of lightweight ammunition, greatly increasing the number of "stowed kills."

The charts shown in figure 6 and figure 7 illustrate the weight efficiency of the lightweight ammunition compared to conventional brass cased ammunition. The two most important components of any ammunition in terms of lethality are the bullet and the propellant. Any remaining components present are essentially dead weight that facilitates handling, loading, or ignition. Comparing the weight distributions for the lightweight ammunition and the M80, it was found that the non-lethality producing components of the M80 consume 50% of the ammunition weight, while the weight of those components in the lightweight ammunition was reduced to 25% of the ammunition weight.

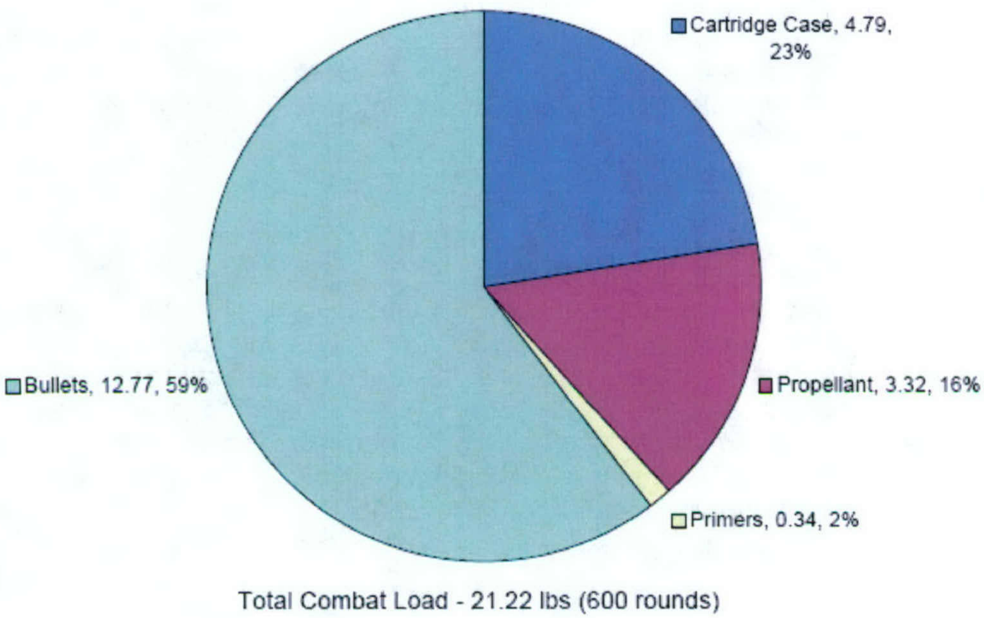

Figure 6
Weight distribution of the Veritay lightweight ammunition concept
(packaging materials not included)

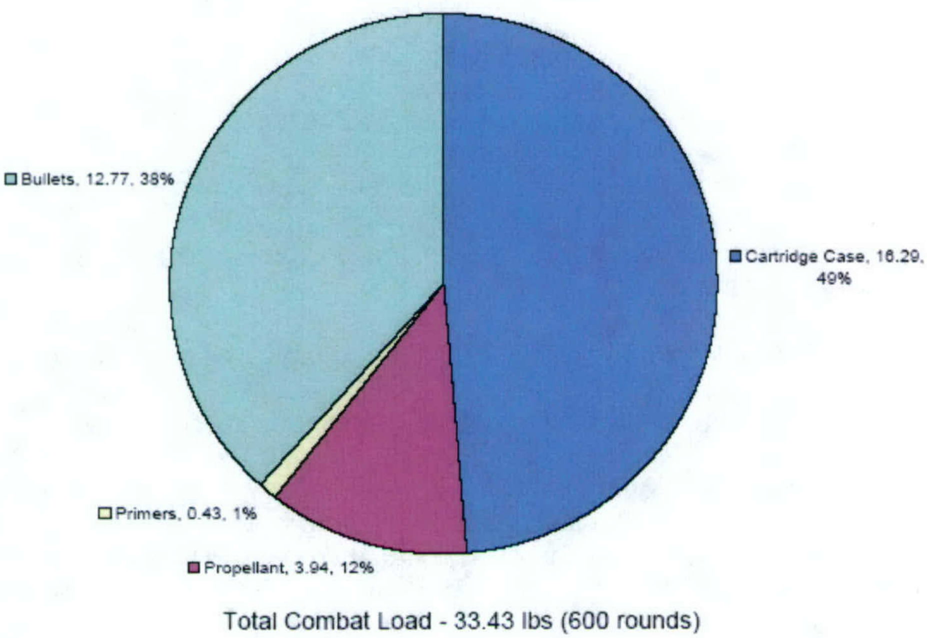

Figure 7
Weight distribution for the conventional M80 ball ammunition for M240B medium machine gun
(packaging material not included)

Synergistic system-wide weight reduction can potentially be found in several areas. The reduced size of the ammunition due to propellant consolidation can reduce weapon weight and improve packaging efficiency. Non-circular cartridge cross-sections can allow even greater packaging efficiency. Reduced ammunition weight and increased packaging efficiency will produce significant improvements in the logistics train. A linkless feed system that is driven by the weapon can reduce the weight and complexity and improve the reliability of the ammunition clip or magazine.

CONCLUSIONS

The goal of this project was to design, develop, and test a lightweight ammunition concept that offered at least a 30% reduction in weight compared to conventional brass-cased ammunition, and a substantial reduction in size. It has been demonstrated that the combination of a lightweight cartridge case and thermally consolidated propellant can produce a weight reduction of nearly 37%, while maintaining ballistic performance. While the work performed during this project addressed the 7.62-mm caliber, the design con-cepts and lessons learned can be applied to other calibers. The ammunition concept discussed in this report can be easily scaled up or down to the caliber required by the end-user without an extensive re-development effort.

The anticipated benefits of this ammunition concept are:

- 36.5% weight reduction compared to M80 ball ammunition
- 45.7% weight reduction if a linkless feed system is used
- Ballistic performance equal to M80 ball
- Scalable to other calibers (smaller or larger)
- Reduced cartridge size can lead to reduced weapon weight
- Reduced cartridge size improves packaging efficiency/reduces logistics burden
- Can enable warfighter to carry additional ammunition or other gear
- Cost competitive with conventional ammunition

The benefits of the lightweight ammunition developed by Veritay Technology, Inc. during this project will increase the effectiveness of the warfighter by allowing him to carry additional rounds of ammunition, or to carry additional gear that will increase combat effectiveness. The technologies employed in the lightweight ammunition are mature, and the ammunition design will scale to other calibers to support a family of lightweight weapons.

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